APPARATUS FOR THE STUDY OF COMPARATIVE TRANSPIRATION

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(WITH FIVE FIGURES)

The quantitative study of the ecological factors of the habitat naturally leads to a similar investigation of the responses of the "growth-forms" to these elements of the habitat. Thus the investigation of the comparative evaporation of various local habitats has led to a complementary study of the comparative rates of transpiration of the plants occurring in them. In this latter work an effort has been made to obtain graphs of the hourly transpiration rates under a great variety of conditions of temperature, light, and humidity. For comparative purposes these data are being collected (1) by the synchronous exposure of several plants, and (2) by determining the ratios between the transpiration rate and the rate of evaporation from a standard vaporimeter.

It is evident that for conducting a study of this kind, in which data regarding the effects of stimuli and latent periods are essential, the determination of the water losses by the method of weighing at intervals of several hours is, to say the least, unsatisfactory. A very perfect apparatus for the automatic weighing and recording of evaporation rates has been described by GANONG in this journal.[1] For comparative purposes, however, several of these instruments are required, making the cost beyond the means of at least some laboratories. The following apparatus is essentially a modification of the Ganong transpirograph, developed for the special purpose of comparative work. Its efficiency, combined with its comparatively small cost, has made it seem worth describing in advance of the discussion of the data which are being obtained by its use.

The complete outfit, as shown in fig. 1, consists of a hygrothermograph, a chronograph, chemical balances, weight droppers,

[1] New precision appliances for use in plant physiology. BOT. GAZETTE **39**:145. 1905.

and irrigators. Of these the chronograph, the weight droppers, and the irrigators are new forms of well-known devices.

THE CHRONOGRAPH.—Where synchronous records are desired, it seemed that a chronograph having several pens to mark on the same sheet of paper would be more desirable than several separate instruments, not only on account of the decreased cost, but also

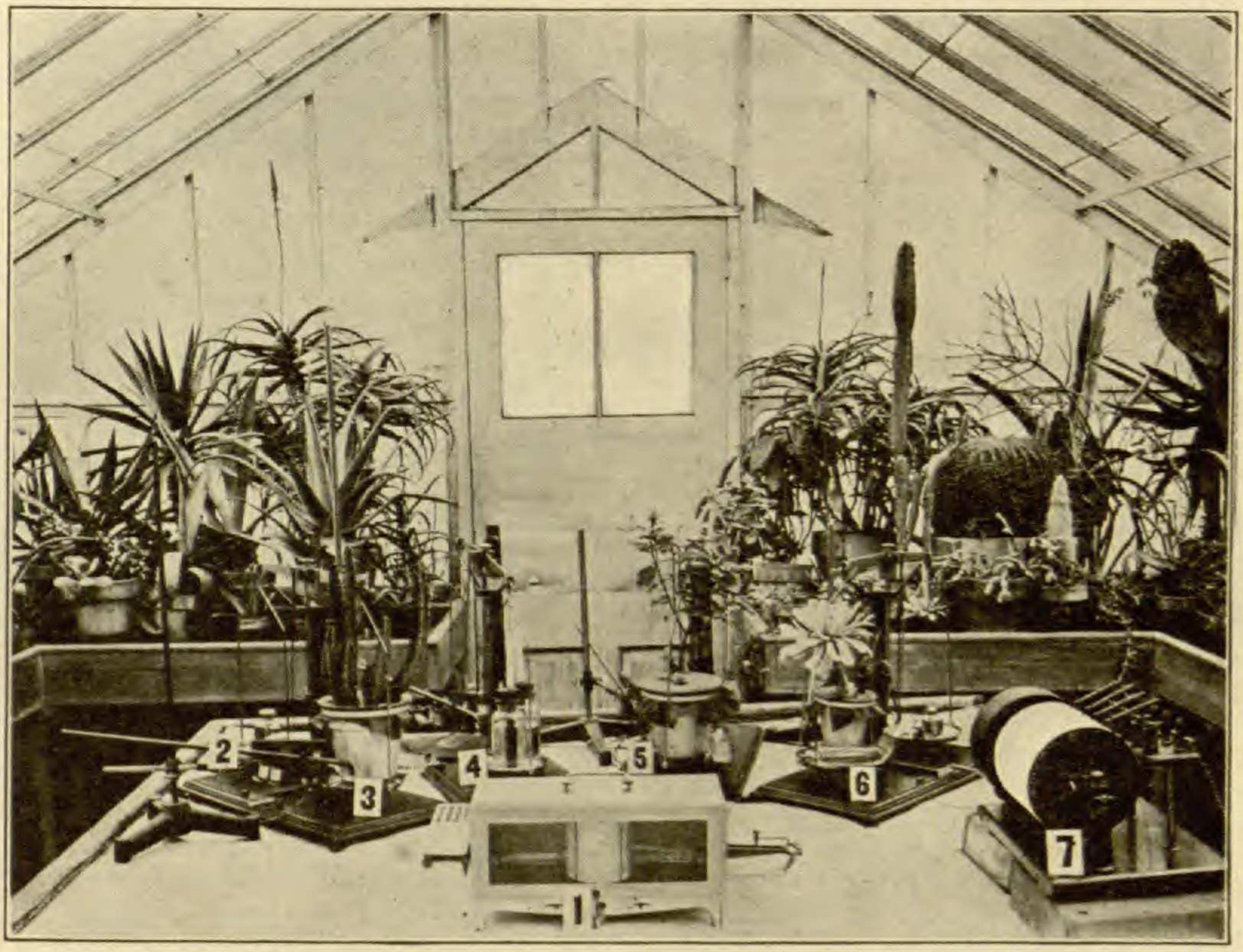

FIG. 1.—Complete apparatus for recording comparative transpiration data: *1*, combined hygrograph and thermograph; *2*, weight dropper; *6*, irrigator; *7*, chronograph.

because the errors of the clocks would be eliminated. The chronograph shown in fig. 1 has an eight-day movement attached to a horizontal cylinder 15 cm. long and 15 cm. in diameter. The record is made by pens which mark a continuous line except when drawn aside by an electro-magnet. At present the instrument bears four pens, but it is so constructed that four more may be added on the same side, thus increasing its capacity to eight synchronous records. By lengthening and shortening the hairspring the space traversed by the pen in one hour may be varied from 2 to 5 mm. In the

latter case the cylinder makes a complete revolution in about four days. A strip of ordinary millimeter cross-section paper is used for the record sheet. In class experimentation this recording clock has a variety of possible uses aside from this particular experiment.

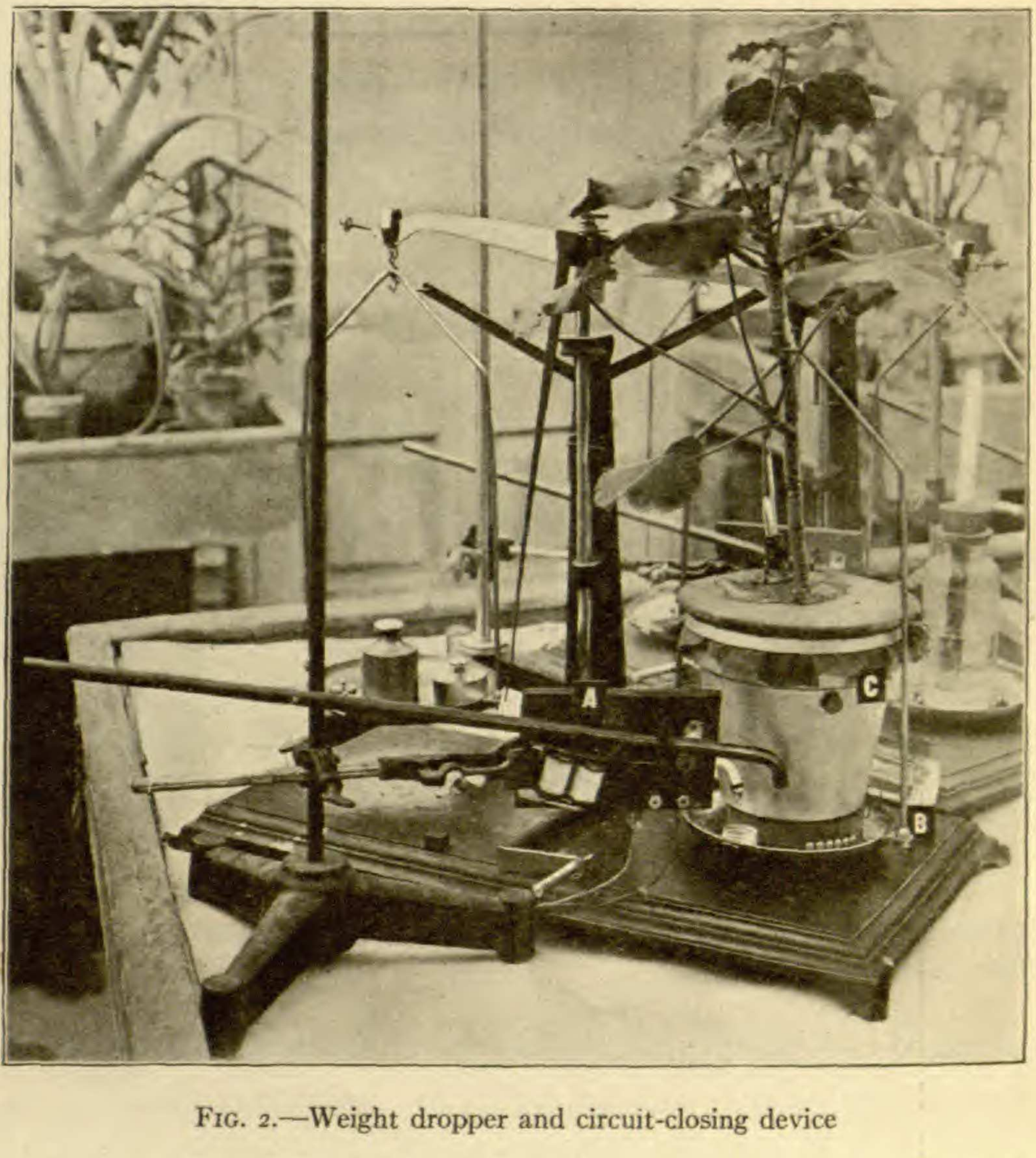

FIG. 2.—Weight dropper and circuit-closing device

THE WEIGHT DROPPERS.—As in the Ganong transpirograph, the recording of the water losses depends upon an electrically actuated mechanism which drops a definite weight in the form of a one-fourth-inch ball upon the scale pan whenever the pan reaches a certain height. As shown in fig. 2, the circuit-closing device consists of two platinum points just beneath the delivery tube

which dip into a small cup of mercury on the scale pan whenever a balance is established. The one gram weights are too heavy to obtain satisfactory records from many of the extreme xerophytes. For these plants I am using hollow brass balls standardized to 0.4 gm. These are not as light as could be desired, but they are better than the gram weights. To be very satisfactory for comparative purposes, the interval between records should not exceed two hours. Where great differences exist between day and night rates, I have used the fractional weights at night and the gram weights during the day.

THE IRRIGATORS.—Two points which became evident in the early experiments are that the water content of the soil of the plants to be compared must be essentially the same, and that the water content must be essentially the same throughout the experiment. The ordinary method of watering at 24-hour intervals did not give satisfactory results in some instances. In one experiment the ratio between two plants on successive days was reversed on account of differences in soil water content. To avoid errors of this kind the principle of irrigating plants by porous cups suggested by LIVINGSTON[2] was brought into use, and the apparatus shown in fig. 3 was constructed. It consists of a slender porous cup similar to those used in my vaporimeters.[3] This is readily introduced into the soil of a 3-, 4-, or 5-inch pot by removing a core of soil with

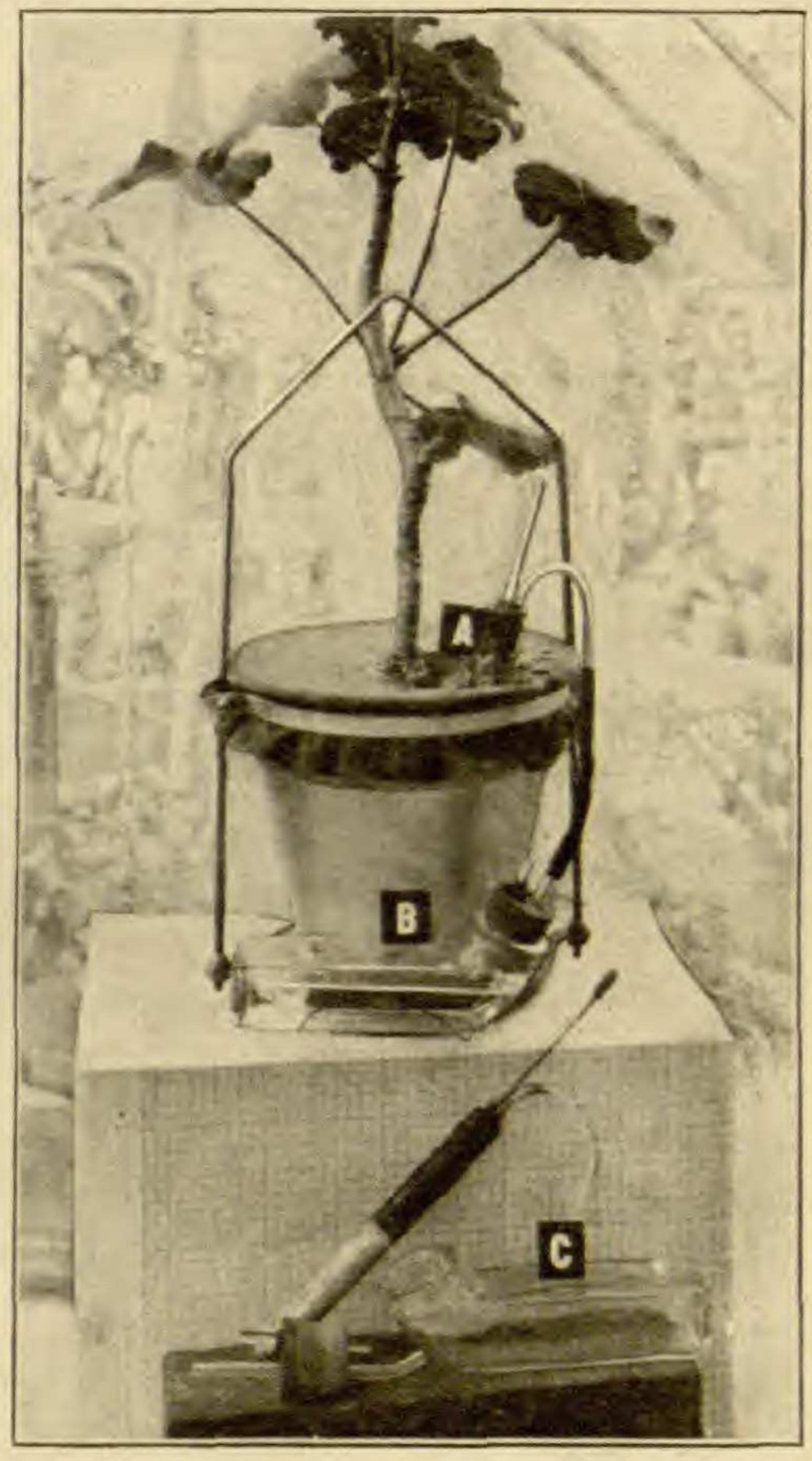

FIG. 3.—Details of the irrigator, showing porous cup, water reservoir, and connections.

[2] A method of controlling plant moisture. Plant World 11:39. 1908.

[3] A simple vaporimeter. BOT. GAZETTE 49:459. 1910.

a cork borer slightly smaller than the porous cup. The cup is connected by glass and rubber tubing to a horizontal reservoir made of a flat-sided "specimen bottle." The reservoir is supported at the side of the scale pan by a light wire bracket, attached to a flat cork upon which the aluminum shell containing the plant rests. The second tube at the upper end of the porous cup affords an easy method of filling the cup. After the water has been drawn up, this tube is sealed with cement. The air needed to replace the water in the reservoir enters through the stopper by a capillary tube. By extending this capillary tube beneath the water level, the rate at which the water is removed may be approximated by the rate at which air bubbles enter. This may yield interesting results concerning the relative time of the absorption and transpiration maxima. It is of course open to the same objections as the Reinke method of determining the relative rate of photosynthesis in submerged plants.

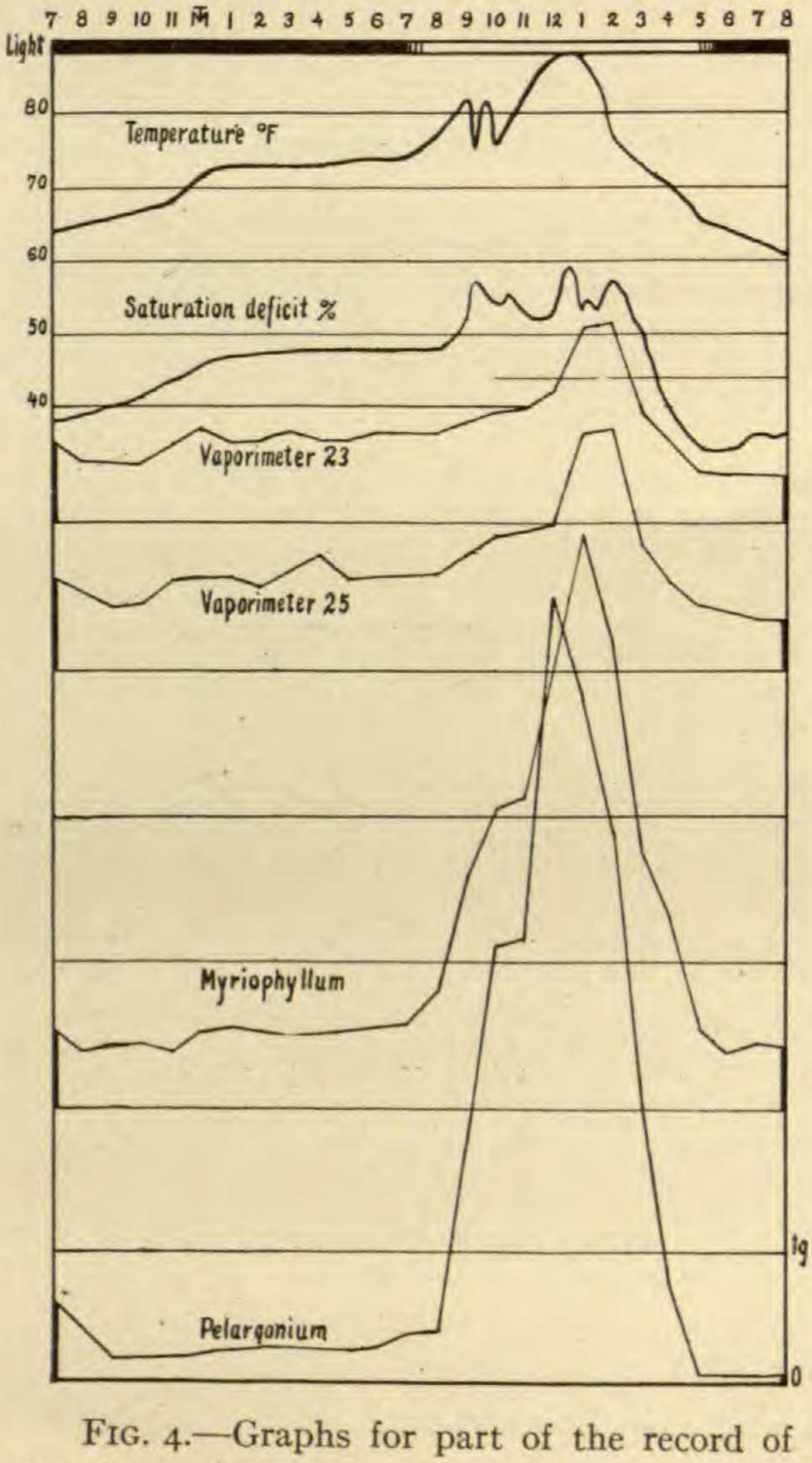

FIG. 4.—Graphs for part of the record of experiment 8.

The aluminum shells devised by GANONG[4] are very satisfactory for inclosing the pots. The 15 cm. shell seems to be the most satisfactory to use, regardless of the size of the pot, because of the larger volume of air inclosed. I have no quantitative data to prove

[4] BOT. GAZETTE 41:212. 1906.

this, but the plants appear to withstand the experimental conditions perfectly in this largest shell and not so perfectly in the more closely fitting ones. When the irrigators are used, it is convenient to have a 1 cm. hole in the side of the shell closed by a cork through which the air may be changed at intervals by means of a small bellows. This avoids the necessity of removing the roof from the shell during

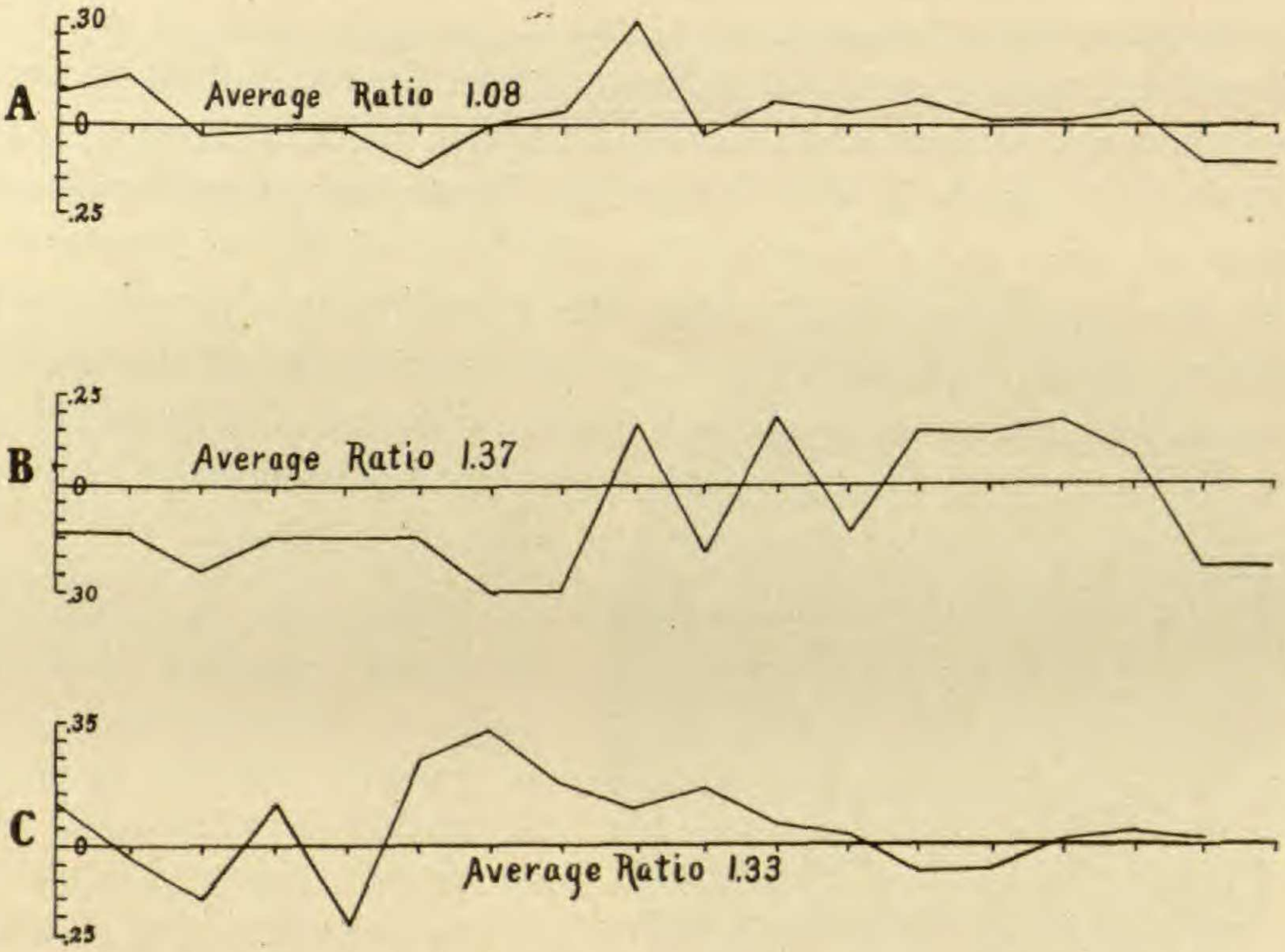

FIG. 5.—Departures from the average ratio between two synchronous records calculated to 2-hour periods: *A*, two vaporimeters; *B*, two irrigated pelargoniums; *C*, two pelargoniums watered at 24-hour intervals; average ratios calculated from the total water losses.

the experiment. The smaller pots are brought to the upper level of the shell by being placed on a strip of aluminum bent in the form of a W. This raising of the pot above the level of the water reservoir is necessary to prevent flooding of the soil.

In constructing the graphs from the actual records and in calculating the ratios, an engineer's slide rule has been found to be a great time saver. Fig. 4 shows the complete record for a portion of experiment 8.

To determine to what extent two records may be expected to

coincide by this method of recording, six experiments of two to five days' duration have been performed. The graphs shown in fig. 5 exhibit the actual ratios for 2-hour intervals in comparison with the average ratio for the entire experiment, for synchronous records of two vaporimeters (*A*), two irrigated pelargoniums (*B*), and two pelargoniums watered at 24-hour intervals (*C*). These partial records are sufficient to show that variations in the ratios between records must be greater than 0.3 in order to be significant. It will be readily seen that the variations in the actual records sufficient to produce this variation in the ratios are very small fractions of a gram in most instances. There are various explanations for these minor irregularities: the impossibility of estimating the hourly loss accurately when the gram-interval extends over several hours; shadows made by the framework of the greenhouse; differences in exposure to light; differences in irritability, etc. Whatever their causes, they must not be overlooked in comparing plants of different species and different habitats.

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